Evidence on the impacts of long-term cassava-based conservation agriculture systems on soil organic carbon and greenhouse gas emissions in Cambodia

ABOUT THIS BRIEF

The research brief highlights the impacts of Conservation Agriculture (CA) on soil organic carbon (SOC) sequestration and greenhouse gas (GHG) emissions in Cambodia's upland crops. Findings highlight that soils under CA management act as a soil sink, improving soil health, mitigating climate change and supporting the national food security strategy. The study underscores the need for policy support to scale CA practices.

STATUS OF GHG EMISSIONS AND SOIL RESOURCES OF CAMBODIA

In 2019, agriculture, forest conversion and other land use (AFOLU) were the primary sources of the country's greenhouse gas (GHG) emissions with the average rate of 4 tons CO_2 equivalent (CO_2-e) per inhabitant and per year.

In 2022, agriculture contributed 22% to the GDP representing the 3rd sector. Despite substantial efforts made by the Royal Government of Cambodia to sustain the growth of the agriculture sector, soil fertility depletion and climate change impacts could undermine these efforts.

The ongoing intensification of agricultural practices that rely mainly on mono-cropping of several key crops have caused significant negative effects on the country's soil resources leading to soil degradation, decrease of key ecosystem services, and the loss of biodiversity.

The annual cost of land degradation was estimated at 677 M USD (8%) of GDP in 2016. Every single US dollar of investment on soil degradation restoration was estimated to have a net return at 3 US dollar. This underscores the necessity of adopting sustainable land management practices to overcome land degradation and reducing GHG emissions, particularly through the accumulation of soil organic carbon (SOC) representing the foundation of agricultural sustainability and a win-win strategy to achieve the country's commitment in reducing GHG emissions.

EVIDENCE FROM THE IMPACTS OF LONG-TERM CONSERVATION AGRICULTURE SYSTEMS ON SOC SEQUESTRATION AND GHG EMISSIONS

Through the support from the ASSET project, using three long-term experiments on red Oxisol at Bos Khnor Conservation Agriculture Research Station, Chamkar Leu, Kampong Cham, the department of agricultural land resources management of the General Directorate of Agriculture (DALRM/GDA) with the technical support of CIRAD, conducted a study that aimed at:

(i) Assessing the changes in SOC stock from three main rainfed annual crops (i.e., maize, soybean and cassava) comparing conventional plough-based management (CT) and conservation agriculture (CA)-based cropping systems for a period of 10 years (2011-2021, diachronic study),

(ii) Quantifying the impact of CT and CA systems on GHG (CO_2, CH_4 and N_2O) emissions from cassava-based production systems from April 2022 to April 2024.

Fig 1. The annual accumulation rates of SOC from the three long-term experiments on the red Oxisol at Bos Khnor station

The annual increase rates of SOC stocks (0-100 cm depth) of CA systems of the maize, soybean, and cassava-based systems (interval of 10 years: 2011-2021):

- CA maize systems: +0.86 to +1.47 tons C/ha/yr (mean = +1.21)
- CA soybean systems: +0.65 to +1.00 tons C/ha/yr (mean = +0.86)
- CA cassava systems: +0.70 to +1.07 tons C/ha/yr (mean = +0.91)

The diachronic analysis of the three experiments showed positive increases in SOC stock (0-100 cm depth) under the CA systems, with gains ranging from +0.65 to +1.47 tons C/ha/yr. In the cassava experiment, where GHG emissions were quantified, the SOC sequestration rates under CA systems ranged from +0.70 to +1.07 tons C/ha/yr. This accumulation offsets global warming potential (GWP100), at a 100-year time scale[1], by removing -2.58 to -3.94 tons CO_2-e/ha/yr from the atmosphere by storing it as SOC stock. In comparison, CT removed only -0.52 tons CO_2-e/ha/yr, which was about 4 times lower than CA systems.

The results of the GHG emissions indicated that the total CH_4 and N_2O emissions were similar between CT (1.05 kg/ha/yr) and the CA systems (0.87 to 1.04 kg/ha/yr) while the dry tuber yields of cassava ranged from 9.6 to 11.2 tons/ha/yr under CA systems, representing an increase of 2% to 16% when compared with CT (9.4 tons/ha/yr). When converting the CH_4 and N_2O emissions into CO_2-e, all cropping systems emitted similar amount with 0.39 tons CO_2-e/ha/yr under CT and from 0.40 to 0.44 tons CO_2-e/ha/yr under CA systems.

Compared to the GWP_{100} impact from the total CH_4 & N_2O emissions, the benefits of SOC sequestration in the soils outweighed the emissions. CA systems contributed to the net GWP_{100} offset by removing between -2.14 to -3.55 tons CO_2-e/ha/yr from atmosphere through SOC storage. In contrast, the CT had a net removal rate of only -0.13 tons CO_2-e/ha/yr.

Mono-cropping under Conventional Tillage (CT), farmers' practices

Total CH_4 & N_2O Emission
1.05 kg/ha/yr

Tuber yield (dry):
9.44 tons/ha

Mono-cropping under CA

Total CH_4 & N_2O Emission
0.87 kg/ha/yr

Tuber yield (dry):
9.63 tons/ha

Bi-annual rotation under CA
cassava - maize rotation

Total CH_4 & N_2O Emission
1.04 kg/ha/yr

Tuber yield (dry):
11.22 tons/ha

Fig 2. Tuber yields and total CH_4 and N_2O emissions under each tillage system (2022-2024)

[1] The 100-year time scale is recommended by IPPC for measuring the global warming potential (GWP) providing standardized long-term perspective on the impacts of GHG emissions on climate change.

KEY TAKEAWAY

The findings emphasize that:

- Agricultural soils in Cambodia (at least the red Oxisols) can be a sink of CO_2 under annual rainfed crops and CA management.
- High SOC accumulation rates were recorded when comparing with international literature and these rates are unique in the region for cassava-based cropping systems managed under conservation agriculture.
- Accumulating soil C = Soil restoration process, improving the adaptation to climate change (retaining more water, enhancing soil biodiversity, recycling nutrients) → open pathways for Sustainable Food Systems.
- Possibility to generate Carbon credits and/or eco-credits (co-benefits related to water quality, biodiversity …).
- By recording similar rates of CH_4 and N_2O emissions between CT and CA, the potential of CA systems as sustainable agricultural practices to maintain food security and mitigate the effects of climate change was highlighted.

The comparison between SOC sequestration and GHG emissions highlighted that CA systems representing credible strategies for the Royal Government of Cambodia to fulfill international conventions (NDC, UNCCD, LDN). In addition, CA systems could also contribute to better farming practices for better products, adding values to the agricultural commodities as **"Green Climate Products"**.

Table 1. The net GWP offset by SOC sequestration (0–100 cm) of each cropping system was calculated from subtraction of the GWP offset by SOC sequestration and the direct GWP by CH_4 & N_2O emissions. Negative values indicate the removal of CO_2-e from atmosphere; positive values indicate the emission of CO_2-e from the soil to atmosphere.

Cropping systems	GWP offset by SOC seq.	Direct GWP by CH_4 & N_2O emissions	Net GWP offset by SOC seq.
	(expressed as tons of CO_2-e/ha/yr)		
Mono-cropping _CT	–0.52	0.39	–0.13
Mono-cropping _CA	–3.94	0.39	–3.55
Bi-annual rotation _CA	–2.58	0.44	–2.14

IMPLICATIONS OF THE FINDINGS

Considering the co-benefits of CA systems on soil health improvement, the findings highlight the ability of the CA systems not only to sequester SOC and to mitigate the impacts of climate change, but also to offer a promising strategy sustaining food security by restoring degraded soils in the country.

To effectively scale up CA systems, policies interventions should consider supporting the access to CA technologies. This includes improving the supply chains for mechanization and technologies that match with the principles of CA, improving access to cover crop seeds, building farmers' capacities, and co-designing CA systems tailored to their specific needs and contexts. Additionally, financial mechanisms (practice or impact-based incentive, loan with lower interest rate …) for farmers could encourage wider implementation and accelerate the shift toward sustainable farming practices.

Photo: Cover crop seeds preserved at the genetic bank of Cambodian Conservation Agriculture Research for Development Center (CARDEC)

RESOURCE

This research brief is a summary of:

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Vira Leng, Rémi Cardinael, Florent Tivet, Vang Seng, Phearum Mark, Pascal Lienhard, Titouan Filloux, Johan Six, Lyda Hok, Stéphane Boulakia, Clever Briedis, João Carlos de Moraes Sá, and Laurent Thuriès

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